

THE ELECTRICAL ENGINEERING DEPARTMENT  
IN THE CENTER FOR INTEGRATED SYSTEMS

The Center for Integrated Systems represents the confluence of university capability in semiconductor integrated circuits with computer systems. Its focus will be the production of new professionals at the graduate level and the collateral production of R & D in these areas. The Electrical Engineering Department at Stanford exhibits a mature research emphasis distributed principally over the component areas necessary to the Center for Integrated Systems. Present and projected emphasis is in the graduate area, with degree programs at the master's and Ph. D. levels. The neighboring industrial community exhibits a similar distribution of technical capability with a very strong emphasis upon a semiconductor industry in which this section has the dominant concentration of that industry in the world. The Electrical Engineering Department has been continuously coupled to that industry and is a significant reason for the strength of the industry in this geographical area.

With its annual production of about 180 M. S. and 45 Ph. D. graduates in Electrical Engineering, Stanford typically ranks first or second in the United States in quantity. Its position in quality of graduate students is correspondingly high. Over the past several years, the median of students admitted and enrolled for graduate study has progressed upward in the 97th percentile on the quantitative part of the Graduate Record Examination, a reliable national index of applicant quality.

In the area of semiconductor materials and integrated circuits, Stanford's Electrical Engineering Department has a powerful position. Its development of a solid-state device and materials program started just before the semiconductor build-up in the Santa Clara Valley--now called "Silicon Valley". Work in semiconductor materials science has been dominant here. A pioneering effort in ion implantation was established, and most recently that effort has moved into the collateral area of laser and electron beam

annealing. Work of national visibility on semiconductor surfaces has proceeded. Over the past twelve years, the most potent integrated circuits laboratory in any university has developed in Stanford's Electrical Engineering Department.

The Electrical Engineering Department has an eminent program in information systems, with a strong faculty of eight members and a graduate student complement of more than sixty. A very strong base, primarily in theoretical work under the leadership of Professor Kailath, has been instituted. Recently the attention of a growing number of faculty members has shifted to problems in which complex computations can be most easily done with special computing structures--array processors, for instance. This new derivative of activity leads directly to one of the major areas of interest in the projected activity in the Center for Integrated Systems.

Our Computer Systems Laboratory exhibits an existing collaboration with the Department of Computer Science in this area central to the Center for Integrated Systems. It is the technical area in the Electrical Engineering Department most attractive to incoming students. A collaboration between the Integrated Circuits Laboratory and the Computer Systems Laboratory has been initiated in the area of computer-aided design, a capability of absolute necessity in the design of integrated systems in the very large scale integration (VLSI) regime. Professor Robert Dutton, of the IC Laboratory, and his colleagues and graduate students have developed a number of essential programs for integrated circuit design and simulation. Perhaps the most prominent of these is the Stanford University Process Emulation System (SUPREM); a hundred copies of this program have been distributed and are in use among the major industrial laboratories.

The magnitude of effort of these component activities is indicative of the strength of program already under way. Table I enumerates the faculty, staff, and budget currently applicable in these four laboratories.

To this point, the activities of the four laboratories represent a research activity of approximately \$7 million, about two-thirds of the total research activity in the Department of Electrical Engineering. The Center



TABLE I. PRESENT STANFORD ACTIVITIES RELATED TO THE C. I. S

<u>Laboratory</u>	<u>Faculty</u>	<u>Grad. Stud.</u>	<u>Res. Assoc.</u>	<u>Technicians</u>	<u>Budget</u>
Integrated Circuits	8	40	14	8	\$ 3.3 M
Solid-State	6	20	6	2	\$ 1.5 M
Computer Systems (w/Computer Science)	12	45	2	6 (Prog./Tech. Aides)	\$ 1.0 M
Information Systems	8	62	1	0	\$ 1.0 M

for Integrated Systems will integrate the activities of these laboratories with a strong common focus.

Support of research programs in the Electrical Engineering Department is dominated by the federal government. In the area represented by the Center for Integrated Systems, research programs have typically been initiated by one or a few faculty members approaching a funding agency as principal investigators. The result is that the research program is spread over a large number of principal investigators and a rather large number of independent governmental entities. A principal exception to this is in the Integrated Circuits Laboratory, where Professor James Meindl has acted as principal investigator on projects which involve a number of his colleagues as research leaders. The largest fraction of the research support comes from governmental agencies connected with the DOD. The IC Laboratory represents an exception, the large Center for Integrated Electronics in Medicine being supported by the National Institutes of Health. However the National Science Foundation, in addition to NIH, provides a significant degree of our support. In the work proposed for the Center for Integrated Systems, the initial research contract will likely come from the Defense Advanced Projects Research Agency (DARPA). The Solid-State Laboratory and the Integrated Circuits Laboratory have present and on-going support from the Materials Science Division of DARPA. The current level of that support is more than \$1.3 million annually. A new program vertically integrated from integrated circuits through computer systems is being proposed to DARPA to add to the present support. During the study phase, where the most attractive target problems will be

identified, the support level of this proposed work exceeds \$1 million per year.

The Center for Integrated Systems will be coupled to the integrated circuit and computer industries. The Department of Electrical Engineering has for a quarter century had strong industrial connections. These connections serve as a beginning point for the connections of the Center for Integrated Systems, particularly since many of the present connections of the department are with companies in integrated systems. A first basis of the Stanford industrial connection is the production of a selected and well-prepared corps of graduate students to further American efforts in integrated systems. The shortage of talented and educated manpower is the principal limit at this point to the continuing rapid development of the electronics revolution in integrated systems.

A remarkably productive cooperative plan of graduate education was established in the Electrical Engineering Department at Stanford under the leadership of Provost Emeritus F. E. Terman, then Dean of Engineering. In this plan, able employees are recruited by companies with the added attraction of Stanford graduate education. They get master's degrees in two years while working full time with the companies. The product of this plan, integrated over the quarter century of its operation, has been beneficial, both to the industry neighboring Stanford and to the Electrical Engineering Department itself. Presently there are 142 electrical engineers involved with the Honors Coop Program. The form of the cooperation with industry has evolved over the years. Closed-circuit television has been in place since 1969. Now, each year more than 80 EE courses as well as 18 courses in Computer Science are broadcast over the closed-circuit television system. The television system, put in place solely with contributions from the industry it serves, has had a powerful influence. One of the most interesting by-products is the ability to make videotapes of regular classes. These are played in remote locations using a clever suggestion of Professor Gibbons called Tutoed Videotape Instruction (TVI). This capability makes it possible to extend the educational arm of the Electrical Engineering Department far beyond the



range of Stanford's TV transmitter. For the Center for Integrated Systems this flexible communication system is available for other forms of communication which will evolve and become important in the central role that Stanford will play in disseminating its work and contributing to the growth of integrated systems in the United States.

The Department of Electrical Engineering participates in three affiliates programs which maintain a close liaison with interested industry and provide more than a half-million dollars of unrestricted income to serve our educational and research needs. The Solid-State Affiliates Program was the first and is presently the largest of these programs. It serves 32 companies. The Computer Forum, which is operated jointly by the Computer Systems Laboratory of the EE Department's Stanford Electronics Laboratories and the Computer Science Department, serves 25 companies. The Information Systems Affiliates serves 13 companies. In these programs, technical liaison is maintained by faculty members who have individually close relationships with the technical representatives of the affiliated companies. In each program, an annual technical review in the appropriate area is held.

Recently industrial organizations have begun to participate in the support of our research programs. A number of special grants have been set up. The first of these was a grant of Hewlett-Packard to the Integrated Circuits Laboratory in the area of computer-aided design under the direction of Professor Robert Dutton. Stanford, with a group of doctoral students under Professor Dutton, conducts research in an area of mutual interest to our integrated circuit effort and to Hewlett-Packard. A number of other similar programs have been set up. Recently a Departmental Research Assistantship Program was initiated whereby master's candidates can be supported on industrial grants or contracts which are conducted in a way to be compatible with the same kind of program supported by the federal government. Because of the intense industrial interest in integrated systems, the Electrical Engineering Department anticipates a greatly increased base of R & D support from the semiconductor and computer industry.

New industrial ventures have been initiated by faculty members, staff members, or graduate students, frequently based on research work done at Stanford and frequently utilizing the university environment as an incubator for these new ventures. The most well-known of these examples is, of course, Hewlett-Packard, which was started by William Hewlett and David Packard on the basis of an RC audio-oscillator developed by Hewlett for an engineer's thesis in the 1930s. Another example is Varian Associates, which was formed after World War II to pursue work in the microwave tube area. Russell Varian invented the Klystron at Stanford in the late 1930s, and its development during World War II played a tremendously significant role in the American war effort. There are a number of intermediate examples and certainly more will follow, but two recent ones can be identified which are particularly relevant to the Center for Integrated Systems. Stanford's Integrated Circuits Laboratory was founded by a project to develop custom integrated circuits required for a reading aid for the blind. The necessary photo-transistor array and custom driver ICs for the Optacon (OPtical to Tactile CONverter) were developed in our then-new IC Laboratory. After successful operation of test Optacons at Stanford, a company was formed for production. Telesensory Systems, Inc. now operates successfully in the industrial park, employing some 190 people and distributing sensory aids for the handicapped all over the world. A more recent example is Cromemco (CROthers MEMorial COMpany; Crothers Memorial being the graduate dormitory for engineering students), set up by Drs. Harry Garland and Roger Melen to manufacture microcomputers for the personal computer as well as commercial computer market. It is interesting to report that Cromemco has already pledged \$100,000 of equipment to the new Center for Integrated Systems, representing our first industrial gift for the establishment of the Center. Integrated systems represents a potent area for establishment of further ventures, and the environment of the Electrical Engineering Department will be maintained in a form to facilitate that development.

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